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Pneumatophore root clusters as nuclei of woody plant establishment in a Bornean freshwater swamp forest

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Summary. Pneumatophore root clusters, common in some freshwater swamp forest sites in the Mulu National Park in Sarawak, in west Borneo, are the major foci for the development of litter mounds that form the nuclei of woody plant establishment. These microsites may be favourable for woody plant establishment because they are better aerated than the intervening, usually waterlogged parts.

Pneumatophore or "breathing" roots are commonly formed by a number of tree species in both freshwater and peat swamp forests in Southeast Asia. Species in Borneo which form peg-like or loop-like ("knee") pneumatophore roots include *Alstonia pneumatophora* Backer ex Berger (local name *pelai paya*, Apocynaceae), *Dyera polyphylla* (Miq.) Ashton (*jelutong paya*, Apocynaceae), *Lophopetalum multinervium* Ridl. (*perupok paya* or *dual*, Celastraceae), *Madhuca motleyana* (de Vr.) Baehni (*ketiau paya*, Sapotaceae), and *Polyalthia glauca* (Hassk.) Boerl. (*selukai*, Annonaceae). These pneumatophore roots have large air spaces in their tissues and supposedly function to increase oxygen intake for the root system, which otherwise has to function in a comparatively oxygen-poor environment in waterlogged or frequently inundated substrates in swamp forests.

In lowlying stretches of some freshwater swamp forests in northern and western Borneo, such pneumatophore roots can develop along lateral roots growing some distance away from the trees that bear them, and often clusters of peg-like or loop-like pneumatophore roots are common. Around such clusters of pneumatophore roots, as around fallen branches or logs in the forest, litter mounds frequently build up, and appear to be associated with concentrations of woody plant seedlings and saplings (Fig. 1). This paper reports the relative frequency of such root-cluster litter mounds encountered in a patch of freshwater swamp forest in the Mulu National Park, Sarawak, as estimated along a 2-km

trail from the Park Headquarters complex to the Deer Cave, and the possibility that such mounds are nuclei for the establishment of woody plant seedlings.

Fig. 1. Woody plant regeneration establishing on litter mounds forming around pneumatophore root clusters in a freshwater swamp forest site in the Mulu National Park, Sarawak (photo by W.M. Poon).

Methodology

The excellent plank walk leading to the Deer Cave from the Park Headquarters complex was regarded as a transect where it passed through a patch of freshwater swamp forest, as it was constructed with minimal disturbance to the vegetation. The census was carried out along one side of this plank walk, and strips of wood used to hold down a wire-meshing over the surface of the plank walk, placed at 1-yard intervals, were used as markers for including 100 such sections along the plank walk as units in the census.

For each of the 100 sections of the plank walk transect so demarcated, a visual count was made within an area 2m wide, and from one edge of the plank walk, of
(a) pneumatophore root mounds with and without woody plant regeneration;

(b) other types of mound (such as those forming around logs, fallen branches and tree bases) with and without woody plant regeneration; and
(c) woody plant regeneration (number of seedlings or saplings) not associated with any type of mound (usually in the waterlogged lower lying sites among mounds).

The regeneration censussed included any woody plant developing a stem up to about 5 cm diameter at the base. Herbaceous plants, palms and pandans were excluded from the census; these were abundant and generally appear to be more tolerant of waterlogging. Mounds developing around tree bases exceeding 5 cm diameter were excluded from the census.

Results

The number of pneumatophore mounds per section of the transect (N = 100, range = 0-8, median = 2.0) were found to be significantly higher (Mann-Whitney U-test, p = 0.00) than the number of other mounds (N = 100, range = 0-1, median = 0.0).

There were also significantly less seedlings and saplings (Mann-Whitney U-test, p = 0.00) not associated with any mound (N = 100, range = 0-3, median = 0.0) than those establishing on pneumatophore mounds (N = 100, range = 0-8, median = 1.0), assuming there is only one seedling or sapling per pneumatophore mound.

Analysis with the Kruskal-Wallis test also showed significant differences (p = 0.00) among pneumatophore mounds with seedlings or saplings (N = 100, range = 0-8, median = 1.0), other mounds with seedlings or saplings (N = 100, range = 0-1), median = 0.0), and seedlings or saplings not establishing on any mound (N = 100, range = 0-3, median = 0.0). There was no significant difference between the number of non-pneumatophore mounds with regeneration and the number of seedlings or saplings not associated with any mound.

Implications for swamp forest regeneration

The factors that are crucial to the quality of tree regeneration in a swamp forest include the number of mother trees seeding at different times, the degree of canopy opening (which influences the amount and quality of radiation reaching the forest floor and, thus, also the proliferation of ground shrubs and herbs that may shade out tree regeneration), and the availability of sites that favour the successful establishment of woody plants. Our observations indicate that raised mounds are the nuclei of woody plant establishment in such frequently waterlogged freshwater swamp forests, and that the pneumatophore clusters developing are the major foci for such mound development. Such root cluster mounds may be important to woody plant regeneration in the first place because of a general inability of most woody plant seedlings to establish in waterlogged, oxygen-deficient conditions in swamp forest, so that they are more able to survive in better aerated conditions in mounds.

In north and west Borneo, such as in the Sugut-Paitan, Kuala Labuk and Kuala Kinabatangan swamps of Sabah, some areas with freshwater swamp forest rich in *Lophopetalum multinervium* may be good sources of commercially extractable *perupok paya* timber. Foresters have often observed the difficulty with which such logged swamp forests, from where there is a tendency to remove a high stocking of mature stems of commercially desirable species such as *perupok*, can recover, if they recover at all. Much of the ensuing changes in floristic composition is due to a drastic alteration of the forest structure, where more open conditions encourage a weedy growth of herbs and pandans that shade out tree regeneration, which is also much reduced by the vastly lower number of immediately reproductive trees remaining. It also appears, from the present study, that when a large crop of such pneumatophore-forming trees are removed or killed in a swamp forest, the proportion of raised mounds present as nuclei of woody plant establishment will be reduced, as the root clusters, which form the bases for such litter mounds, die and decay.

The destruction of the tree canopy in such a swamp forest not only alters the environmental regime within the stand, but also destroys the living framework of pneumatophore root-clusters and the canopy, which are the major elements of a system that ensures the natural regeneration of the forest itself.

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